The laser has been used in the field of oral surgery for a wide range of indications. In this article, we focus on its surgical uses. The success of the surgical treatment of lesions in the oral cavity depends greatly on knowledge of the aetiology and histology of the lesion. There are pathologies that can be treated with laser, such as cancer sores and hyperkeratosis. Others, like candidiasis, cannot be treated with laser. Furthermore, laser has quickly become a predictable and favourable treatment modality for leukoplakia, haemangioma and epulis.

In the last issue of laser, the authors gave an overview on in vitro studies and in vivo animal studies in this field. They continued by giving examples of in vivo studies on humans on the subjects of wound and bone healing supported by laser treatment. Finally, the authors analysed soft-tissue surgery and examples of cancer treatment via CO2, laser and photodynamic therapy under the headline of “clinical studies.” They continue this chapter in the present issue of laser by discussing, among others, leukoplakia treatment, benign diseases and frenectomy. In the conclusion, they sum up the positive effects of laser on oral surgery.

Leukoplakia treatment
Leukoplakia is a premalignant lesion associated with excessive consumption of alcohol and tobacco. Although there is no specific treatment to prevent its recurrence, abandoning these habits can decrease the probability of recurrence, as well as the transformation into malignant tumours.

Vivek et al. treated 28 patients with histologically diagnosed leukoplakia in order to study efficacy, safety and acceptability of lasers, particularly the Nd:YAG laser. After laser treatment, post-operative complications associated with ablation were assessed. They recorded only mild to moderate pain, with slight swelling up to 72 hours post-treatment. A follow-up study was initiated three years later. Approximately 92 per cent of the patients were found to have been cured. Therefore, the authors regarded Nd:YAG laser as an effective tool for the treatment of this pathology.

There are also studies that recommend CO2 laser for the excision of leukoplakia. For example, Reddi and Shafer found the CO2 laser to be of great success in the excision of leukoplakia in their study. They also applied laser to the treatment of erythroplasia and lichen planus.

Treatment of lichen planus
Owing to its inflammatory effects, lichen planus can be painful both in atrophic and erosive forms.
The traditional treatment, therefore, makes use of topical corticosteroids.

Cafaro et al.\textsuperscript{26} conducted a prospective cohort study of 13 patients with lichen planus in order to investigate the effectiveness of LLLT. Patients were given biostimulation by diode laser (904 nm, pulsed mode). In general, a decrease in the size of the lesions and pain, and overall stable results were observed. The authors therefore recommend LLLT as a possible treatment for patients with lichen planus, but recommend that future studies be done with a larger group of patients in order to corroborate their results.

**Aphthous stomatitis**

LLLT has also been used in the treatment of recurrent aphthous stomatitis. The study by De Souza et al.\textsuperscript{27} employed LLLT not as an inhibitor of the process, but for its modulating and healing effect on tissues. The authors assessed the effect of LLLT on aphthous stomatitis in 20 patients divided into two groups. Group I was treated with topical corticoids (triamcinolone acetonide) and group II was treated via diode laser (670 nm, 50 mW). Patients reported a decrease in pain already directly after laser treatment. Four days post-treatment, the lesion had receded completely in group I, compared with complete recession seven days post-treatment in group II.

**Benign diseases**

In this section, pathological entities treated with laser in recent years are discussed. Attention is paid to the technique applied, as well as frequency and impact of the laser used for the respective oral surgery.

Owing to the high frequency of pyogenic granuloma in the oral cavity, especially during pregnancy, Jafarzadeh et al.\textsuperscript{28} reviewed this disease and considered treatments and new approaches. Possible treatment options are, among others, resection by means of a scalpel, cryotherapy, the use of corticosteroids, or the use of an Nd:YAG or CO\textsubscript{2} laser. The authors state that laser treatment can help control bleeding, does not result in adverse effects and is therefore considered a successful treatment method with high acceptance by patients.

Actinic cheilitis is another medical condition that can be treated with laser, since results show a high clinical resolution and low recurrence. Its successful treatment is based on the removal of epithelium while avoiding the resulting scarred tissue. De Godoy Peres et al.\textsuperscript{29} compared two protocols of low morbidity clinico-histologically in which CO\textsubscript{2} laser was used with different parameters. A biopsy was done before and after laser treatment. In both groups, a significant reduction in epithelial dysplasia was achieved. Therefore, the authors recommend the use of lasers in cases of mild to moderate dysplasia.

Adipose tissue tumours are found frequently in the maxillo-facial region, for example on the lips and buccal mucosa. Although these tumours have traditionally been treated with a scalpel, laser can be a valid alternative. Suture is not necessary, and there is only minimal tissue scarring. Capodiferro et al.\textsuperscript{30} is an insightful study on this topic.

**Hyperkeratosis**

Abnormal thickening of the stratum corneum caused by an increase of keratin is known as hyperkeratosis. The biological behaviour of this lesion is related to different histopathological changes. Various therapies, such as the use of scalpel, electrocautery, cryotherapy, PDT and topical medications have been proposed for its removal. Owing to advances in the use of laser in the oral environment, laser therapy appears a promising method for treating hyperkeratosis.

Santos et al.\textsuperscript{31} sought to verify the advantages of CO\textsubscript{2} lasers (10,600 nm) and removed lesions by focusing the beam of light around each lesion. The removed tissue was then sent for histopathological ex-
I research

Fig. 1 _Long-term case of vestibuloplasty. Situation on 15th of June, 2003: no gingiva attached at the lower jaw front.

Fig. 2 _Long-term case of vestibuloplasty. ER:YAG treatment (1,000 µs, 15 Hz, 400 mJ, no water, no air). Very low bleeding, periosteum not damaged. Gain of 10 mm.

Fig. 3 _Long-term case of vestibuloplasty. Removal of peripac periodontal dressing, three days after the surgery.

amination. An improvement in haemostasis was achieved by defocusing the laser beam. The authors assert that this technique is easily applied and without post-operative complications.

Treatment of vascular lesions

Large vascular lesions in the orofacial region are often very difficult to remove. Therefore, the use of laser has been suggested as an effective way to remove major vascular lesions through photocoagulation. Angiero et al.32 investigated the effectiveness of photocoagulation and treated 136 patients with a diode laser. More than 98% of these cases displayed complete remission. The study therefore demonstrated that diode laser treatment can prevent recurrence and complication, while the healing time is shortened.

Ostectomy

Stübinger et al.33–36 closely studied the use of Er:YAG laser on bone tissue and its biological effects. Applications range from different kinds of ostectomy, taking grafts from a tubercle and the chin, as well as tooth extraction. Among the benefits of Er:YAG laser treatment are high accuracy without wasting bone, along with a low risk of traumatising soft tissue or tissue charring, or of any complications in the healing of wounds. In order to achieve the best results, Stübinger et al.33–36 advocate the use of planning software. The amount of time needed for the surgery and the lack of depth control are among the disadvantages of the Er:YAG laser.

Third molar

Post-operative pain and oedema are common after the surgical removal of the lower third molar. Traditionally, non-steroidal anti-inflammatory drugs and steroids have been used to treat these symptoms. LLLT has only recently been considered as a possible analgesic agent to control post-operative pain, lock-jaw or inflammation. Markovic and Todorovic27 compared the analgesic effects of two anaesthetics, the use of LLLT and the administration of diclofenac in their study. Compared with the control group, who only received regular post-operative recommendations, participants treated with laser showed significantly reduced post-operative pain.

One year later, Markovic and Todorovic28 studied the effectiveness of dexamethasone and the use of LLLT in reducing post-operative swelling. The study was conducted in 30 patients divided into four groups. Group I was irradiated immediately after the surgery. In addition to laser, an intramuscular injection of 4 mg dexamethasone was administered to group II in the internal pterygoid muscle. Group III was given 4 mg of systemic dexamethasone (intramuscular injection in the deltoid region) in addition to LLLT, which was followed by 4 mg dexamethasone intra-orally six hours after surgery. Group IV was the control group and received only the usual post-operative recommendations. Group II showed the lowest incidence of oedema. The authors concluded that LLLT can be recommended for the reduction of inflammation, an effect that can be increased by topical corticoids.

Amarillas-Escobar et al.39 conducted a similar study on the extraction of wisdom teeth. Their study employed 15 patients who were treated with a diode laser (810 nm, 100 mW) intra- and extra-orally, and a control group of 15 patients who were not irradiated. The experimental group showed no statistically significant differences compared with the control group, although a reduction in post-operative pain, swelling and lock-jaw was detected.

Frenectomy

The term “frenectomy” refers to the complete removal of the frenulum from either the lip or the tongue. This can be done by either conventional surgery using a scalpel or laser. Recently, possible post-operative discomfort for the patient has been widely discussed.

Haytac and Ozcelik40 randomly selected 40 patients for their study who had originally been intended to undergo another form of treatment. Each patient was asked to rate functional complications and pain according to a scale from one to seven. All of the patients perceived laser application positively.
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and experienced reduced discomfort with laser. See for example a long-term case of vestibuloplasty from 2003 by Prof. Dr. Gerd Volland, where no gingiva was attached at the lower jaw front (Fig. 1). After treatment with Er:YAG laser (1,000 µs, 15 Hz, 400 mJ, no water, no air), only very low bleeding occurred and a gain of 10 mm was noted (Fig. 2). Three days after the surgery, the periodontal dressing was removed (Fig. 3), and the patient was free of pain seven days after the surgery (Fig. 4). The healing was completed six weeks after the surgery and a gain of 7 mm was observed (Fig. 5). Three years later, the final gain was set at 5.5 mm and no scarring occurred (Fig. 6). A follow-up in 2009 showed no recurrences and stable results (Fig. 7).

Pathology of the salivary glands

Mucoceles, ranulas or sialolithiasis can result in obstructive salivary-gland pathologies. Mucoceles are produced by an accumulation of mucin from a ruptured salivary-gland duct, usually caused by local trauma. They are characterised by a high percentage of relapse. Two approaches to removing mucoceles have been suggested in the literature: resection by either scalpel or CO2 laser. Yagüe-Garcia et al.\(^4\) compared the effectiveness of using a scalpel with that of a CO2 laser in removing mucoceles in their study. They treated 38 patients using a scalpel and 30 patients using a CO2 laser (5–7 W). The results showed a repetition rate of 8.8% for the conventional scalpel ablation. In 13.2% of the cases, complications such as fibrous scars arose. In the laser group, a follow-up study at 12 months showed no complications or recurrence. The authors therefore recommend laser treatment, since its results are more predictable and its recurrence rate is lower than that of the traditional treatment. Furthermore, fewer complications occur. Huang et al.\(^4\) contributed to this line of argumentation in reporting on laser vaporisation, a procedure that they recommend for children and non-cooperative patients especially.

Ranulas are due to an accumulation of mucin caused by the obstruction of a salivary-gland duct (generally that of the sublingual and submandibular glands), which is usually the result of previous local trauma. Marsupialisation, the removal of the ranula with or without the sublingual gland, laser splitting, and vaporisation of the ranula have been proposed as possible treatments. Lai and Poon\(^4\) present a series of three cases in which ranulas were removed and the injuries vaporised using CO2 laser. The authors state that this treatment can be recommended because of the precision of excision, a clear and sterilised operating field and the low risk of damage to the Wharton’s duct and the gingival nerve. Furthermore, CO2 laser treatment results only in minimal or no recurrence. Zola et al.\(^4\) present an alternative method for removing ranulas. They used an Er,Cr:YSGG laser (1.5 W). The authors found their treatment to offer advantages similar to those found by Lai and Poon.\(^4\)

Sialolithiasis is the mechanical obstruction of salivary glands or their excretory ducts owing to the formation of concretions. It accounts for 30% of salivary gland pathologies and mainly affects the submaxillary glands (83–94%), followed by the parotid glands (4–10%) and sublingual glands (1–7%).

Bisphosphonates

The clinical scope of avascular necrosis caused by bisphosphonates ranges from a single fistula to large areas of exposed necrotic bone tissue. Additional symptoms are paraesthesia, pus, swelling, pain and even fracture. The treatment and management of avascular necrosis resulting from bisphosphonates has proven to be challenging, as no treatments have been effective in the long term. Depending on the patient’s health, possible treatments are the temporary or permanent suspension of bisphosphonate use, use of local or systemic antibiotics or hyperbaric oxygen, and surgical debridement of the lesions. The combination of these therapies may bring about more predictable results.

The use of LLLT has been increasingly favoured as an alternative for treating this type of pathology. In their 2010 review of the treatment of avascular necrosis by LLLT, Vescovi and Nammour\(^4\) explain the effects of the laser on the healing process. Laser stimulation increases organic bone matrix, osteoblast proliferation and capillary growth. Owing to its strong affinity to water and hydroxyapatite, the Er:YAG laser can be easily applied to both soft and bone tissue. Necrotic bone is vaporised in the course
of conservative surgery until healthy bone is reached. Another advantage of Er:YAG laser treatment is its bactericidal action, which increases the healing of bone tissue. Er:YAG laser treatment therefore appears to be a promising technique, since it is regarded as safe, well tolerated by patients and allows minimally invasive treatment of the disease in the early stages.

In a study in 2008, Vescovi et al. present their clinical results of the treatment of 28 patients affected by osteonecrosis. They treated the four groups of patients with an Nd:YAG laser in combination with medical and surgical treatment. Group I was treated medically only, for example via antibiotics and anti-septics. Group II was treated medically and surgically. Group III was treated medically and via LLLT. Finally, group IV was treated medically, surgically and using LLLT. Twelve of the 14 patients treated with LLLT showed significant clinical improvement and reduction in symptoms, nine patients exhibited complete clinical success. The authors state that while the results of their study were not conclusive, the results indicate that Nd:YAG laser treatment has significant potential to treat lesions caused by bisphosphonate-associated osteonecrosis.

In 2010, Vescovi et al. published the results of a similar study. Between 2004 and 2008, 91 patients underwent stomatological observation and 55 sites affected by osteonecrosis were examined. These were divided into four groups and different therapeutic modalities were studied. Group I comprised 13 lesions that were treated medically (1 g amoxicillin three times a day and 250 mg metronidazole twice a day, orally) for a minimum of two weeks. Group II consisted of 17 lesions that were treated medically and via LLLT using an Nd:YAG laser (1,064 nm) once a week for two months. Group III consisted of 13 cases of avascular necrosis treated surgically by the removal of necrotic bone, debridement, alveolar removal and corticotomy. Finally, group IV comprised 12 lesions treated using an Er:YAG laser (2,040 nm) in combination with LLLT using an Nd:YAG laser.

All of the lesions treated with the Er:YAG laser showed a clinical improvement of 100% and complete healing in 87.5% of the cases. The group IV results differed significantly from those of the other groups. The authors suggest that the reason for this is increased accessibility to both soft and bone tissue using the Er:YAG laser. They therefore highlight the role of the Er:YAG laser in the treatment of osteonecrosis and conservative surgery. Consequently, a surgical approach combined with LLLT can be considered the most efficient treatment method for bisphosphonate-associated osteonecrosis.

**Conclusion**

In the last 20 years, lasers have become an excellent tool in oral surgery. Especially in soft-tissue surgery, laser enables the practitioner to excise tumors of different types in a safer and more precise manner than with conventional techniques using a scalpel or electrotome. Modern laser application is based on our knowledge about absorption and other aspects of working with a laser beam. Over the past ten years, 980 nm and 810 nm diode lasers have evolved in particular. They are relatively inexpensive and provide a good compromise between superficial visible absorption and penetration, in favor of achieving optimal coagulation without necrosis in the depths of the tissue.

As a consequence, fibromas, papillomas or lipomas can be removed even from sites like the lips and the cheek with a clear operating field and predictable results. In addition, sutures can be reduced to a minimum and scar formation is also reduced. For hard tissues, erbium lasers appear to be the best choice because of their high absorption in water. Their effect is based on thermomechanical principles, unlike diode lasers, which interact thermally. Therefore, water spray is essential. This way, bone can be removed without inhibiting healing owing to thermal necrosis. Thus applied, laser can increase the positive effects of oral surgery by providing reliability for the surgeon and comfort for the patient.